§5. Fabrication of V-Based Laves Phase Compound Superconductor Synthesized by a Rapidly-Heating and Quenching Process

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Among the C15 type V-based Laves phase compounds, $V_2(Hf,Zr)$ shows very attractive superconducting properties that maximum critical transition temperature (T_c) = 10.1 K, maximum upper critical magnetic field (H_{c2}) above 20 T and insensibility to mechanical strain. In addition, V-based Laves phase compound shows much higher radiation resistance than that of Nb-based A15 compound wires and tapes. Therefore we thought that a V-based Laves phase compound was superior compared with Nb-based A15 phase compounds, and promising as the high field conductor for the advanced fusion reactor. We tried to fabricate the $V_2(Hf,Zr)$ Laves phase compound tapes by applying the rapidly-heating and quenching (RHQ) process to the powder-in-tube processed precursors, and investigated about superconducting properties and microstructures of the samples fabricated by RHQ process.

The high purity metal vanadium (V), hafnium (Hf), zirconium (Zr) powders and tantalum (Ta) tube having 10 mm of inner diameter, 20 mm of outer diameter and 50 mm of length were prepared. The nominal atomic composition of these metal powders was adjusted to be $V_2(Hf_{0.5},Zr_{0.5})$. This mixed powder was well ground by hand, and then the wet ball-mill processing was carried out for 3 hours to homogenize mixed metal powder. After the ball-mill processing, mixed powder was packed into Ta tubes. This composite was cold-rolled with a grooved roller, and this wire was flat-rolled to tapes of about 0.2 mm thickness. The precursor tapes were set into RHQ apparatus, and they were applied to the RHQ treatment in a dynamic vacuum chamber. The schematic illustration of the RHQ apparatus is shown to Fig.1. The precursor tapes, moving at 0.4 m/sec or 1.0 m/sec of velocity, were continuously heated up to the purpose temperatures by resistive-heating during 0.25 sec or 0.1 sec, with a dc current transported between an electrode pulley and a molten metal Ga bath. Subsequently, the tapes were continuously quenched into the Ga bath at about 40℃ from 2200℃. Then, the some as-quenched tapes were additionally post-annealed at several temperatures for 20 hours in the vacuum.

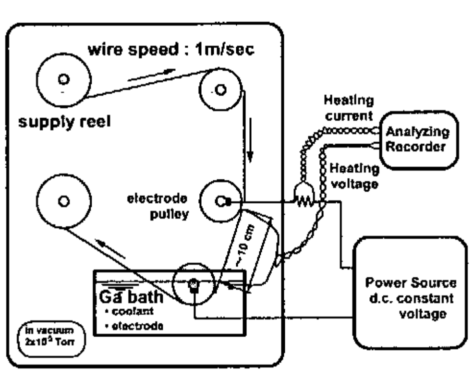

Fig. 1. The schematic illustration of the RHQ apparatus

The XRD patterns of the samples subjected to the RHQ processing are shown in Fig. 2. When the heating temperature was about 1100℃, Laves and β phases were formed directly by the diffusion reaction. As the heating temperature became higher than 1500℃, the peaks of C15 phase were disappeared, and as-quenched core became β phase and amorphous phase. We confirmed that as-quenched samples after RHQ processing had an amorphous phase from results of XRD and EDX. We tried to crystallize C15 phase from amorphous phase by post annealing in the vacuum. Fig. 3 shows that the relationship between offset T_c and heating energy density on the post-annealed samples with tape velocity of 0.4 m/sec. The x-axis values shown in Fig. 3 are estimated heating energy density. The energy is supplied to the precursor tape during RHQ processing from a dc powder supply. We found that the offset T_c values of post-annealed samples were improved with increasing post-annealing temperature, and optimum post-annealing temperature was 700℃. The maximum offset T_c value was obtained 8.88 K when heating energy density was about 4.0 J/mm^3 on the sample post-annealed at 700℃. The heating energy density obtained maximum offset T_c value was shifted to the higher energy compared with that of as-quenched sample.

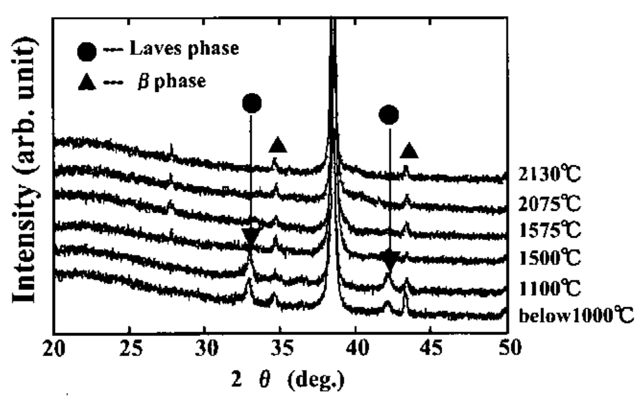

Fig. 2. The XRD patterns of the samples subjected to the RHQ processing

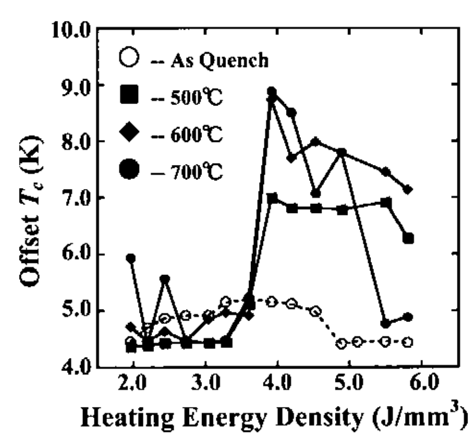

Fig. 3. The relationship between offset T_c and heating energy density on the post-annealed samples